# INTERNATIONAL COOPERATION IN REDUCING MINE HAZARDS

BY E. J. GLEIM

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## SUMMARY

This report describes a trip to Europe in the interest of safety in coal mines. It reviews the Eighth International Conference of Directors of Safety in Mines Research, which met in Dortmund-Derne, Germany, July 5-10, 1954, to discuss results of studies made in different countries to improve health and safety conditions underground. It also summarizes information on subjects of special interest in the United States gained by the writer in visits to mining experiment stations in Belgium, France, and England.

The efforts being made to protect life and property underground were discussed, and ideas and experiences were interchanged freely, not only during the conference but also during visits to the several countries. Helpful information was obtained on many topics of interest, but time did not permit as thorough a discussion on some of them as might be desired.

## INTRODUCTION

Engineers, research workers, and technicians looking for solutions to their problems often benefit greatly by participating in conferences with representatives of organizations working in similar fields. By formal and informal discussions about problems of mutual interest, they gain new ideas and a new outlook with which to attack their own. Thus, in the mine-safety field much good is derived from conferences where specialists in its various phases meet to review progress and to interchange ideas of common interest.

Preeminent among conferences dealing with the subject of safety is the biennial Conference of Directors of Safety in Mines Research. The eighth and latest was held July 5-10, 1954, at the Mining Research Station in Dortmund, Derne, Germany. Here, representatives of 14 nations met to present discussions of 46 papers prepared well in advance and to visit research and testing facilities. Those nations represented were: Austria, Belgium, Canada, England, France, Germany, Italy, Japan, Netherlands, New Zealand, Nigeria, Poland, Union of South Africa, and the United States. The subjects of the papers and the authors are listed at the end of this paper, and the list shows the wide range of topics included. There were too many papers to have them read during the formal sessions; consequently, the delegates were invited to prepare written discussions and questions in advance for presentation during these sessions.

The author, who attended the conference, found that Dr. H. Schultze-Rhonhof and members of his staff of the German research station had been most thorough and efficient in arranging a program for the comfort, convenience, and instruction of the delegates. Each day was divided into separate sessions or periods at which a different chairman presided, and a different topic was assigned for each session. In addition to the formal discussions, a "coffee break" each midmorning permitted the delegates to mingle freely and select those with whom they wished to continue discussions informally. Furthermore, evening banquets sponsored by German

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organizations, such as the explosives industry, the electrical industry, the Coal-Mining Association, and the Westphalian Mining Union, also gave the delegates and representatives of the sponsoring hosts an opportunity to discuss mining problems. All this contributed greatly toward creating an atmosphere of international understanding and good will.

The official languages for the conference were English, French, and German. Each delegate wore a badge bearing his name, with the background colored to indicate the language spoken by the wearer. Thus, blue designated an English-speaking person; white, French-speaking; and red, German-speaking. During the conference sessions translators were stationed in seats in front of the speakers' table and made notes of the speakers' remarks and discussion. At the conclusion, the translators stepped into soundproof booths and repeated the remarks in the chosen languages. Then, by using earphones at each seat, each delegate could operate a selector switch and volume control on a ledge before him to hear the proceedings in the language of his choice. In addition, disk records were made of the discussions for future reference.

The program included visits to the various laboratories where testing methods were demonstrated and explained. Thus, delegates to the conference had an opportunity to obtain firsthand knowledge of equipment used and procedures followed in investigating mining equipment and materials, such as electrical units for machines, explosives, and lamps.

Moreover, as part of the program, special trips to points of interest had been arranged. For example, a limited number of delegates were taken to the Experimental mine near Dortmund where studies on the prevention of mine explosions, detonation products of explosives, rock-dust barriers, and other mine-safety subjects are conducted. Another trip was made to the mining museum in Bochum where there are exceptionally fine exhibits with small-scale models illustrating mining methods, tools, and equipment dating from ancient to modern times. Underneath the museum are areas that simulate underground conditions in a German coal mine, with actual machines and equipment in place.

A third trip was that made to the Mine Rescue Station at Essen. This station is 1 of 3 that are responsible for rescue operations in prescribed mining areas. A fourth station is now under construction. The Essen area is the largest of the three; it is about 30 by 70 miles in extent and includes 154 collieries, 57 coke plants, and 72 byproduct plants. The Essen Station specializes in training leaders in mine rescue operations and rescue work in industrial plants. During 1953, 350 men were trained in 19 courses, lasting 6 days each. The training course is rigorous. In addition to lifting weights and climbing ladders, the trainee (wearing breathing apparatus for mine work) must travel through a four-tier structure in which there are obstacles to get over, through, and around. Less elaborate equipment is available for training rescue workers in industrial plants. The station facilities also include arrangements whereby a number of sets of breathing apparatus may be washed, sterilized, and tested simultaneously. Other activities of the station include: Investigation of self-rescuers, test and certification of fire extinguishers, and analysis of gas and air samples. In 1953, 2,350 such samples were analyzed. The station is well stocked with supplies and equipment ready for use in mine rescue, fire-fighting, and mine-sealing operations.

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## ACKNOWLEDGMENTS

The writer is deeply grateful for the courtesies extended him by personnel of the mining experiment stations in Germany, Belgium, France, and England and for the valuable information gained from discussions with them and with officials connected with the coal-mining industry in those countries.

## INFORMATION OBTAINED AT EUROPEAN MINING EXPERIMENT STATIONS

Since a number of the European mining experiment stations are within a relatively short distance of each other, the author visited several in Belgium, France, and England as well as Germany. In addition to a special assignment to obtain information on preventing conveyor-belt fires, it was desirable also to obtain information on other subjects related to safety in coal mines.

The Belgian station is in Paturages. The French station is at Verneuil, France. England has two stations at which experimental work is done; one of these is at Sheffield and the other at Buxton.

In the following pages the information obtained in the various countries has been classified according to subjects covered.

### Prevention of Conveyor-Belt Fires

The discussion of Paper 24,[2/] Measures for Preventing and Fighting Fires in Belt Conveyors, by Drs. W. DeBraaf and W. Maas of The Netherlands, showed that much experimental work has been done with flame-resistant belts in the different countries because of the severe losses suffered through fires with flammable belt-conveyor installations. The most disastrous of such fires was that at the Creswell colliery, Derbyshire, England, in 1950, which claimed 80 lives. In British mines there are 2,600 miles of belt installations. Because of the Creswell and other fires, the flammable belts are being replaced as rapidly as manufacturing capacity permits with flame-resistant types. These are manufactured with a polyvinyl chloride plastic (PVC) material. Experience with such belts in Germany was said to be much the same as in The Netherlands, in that they do not wear as well as rubber belts. A test belt made in The Netherlands with alternate sections, each 50 meters long, of PVC and rubber, showed that the PVC type had to be discarded long before the rubber. In England, where 29 types had been tried, it was found that more belts had to be removed because of edge wear than because of surface wear.

Statistics on belt fires have disclosed that most of them start at rollers that cannot revolve freely because of seized bearings or because of accumulations of coal and grease around them. The explanation given is that friction of the belt rubbing against retarded rollers causes the nearby material to glow; after the belt has been stopped (as at the end of the shift) the glowing material is fanned into flame, and the belt, being stationary, then easily catches fire. Another important origin of fires has been at the driving pulley owing to friction between the pulley and the belt when the latter has been stopped or appreciably slowed by roof falls or other causes. For this reason, it is important that belts be patrolled regularly to detect incipient fires, particularly after the belts have been shut down. In England it is considered dangerous to use rubber lagging on the drive pulley because slippage might cause overheating. Pulley temperatures must not exceed 180° C. In The Netherlands a 30-percent slip is not considered dangerous, as the belt will remain cool enough, even though the pulley heats.

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2/ Papers prepared for the conference are listed by number in the Bibliography at the end of this report.

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A number of temperature-sensitive devices have been developed to stop the driving motor when the pulley overheats. Some doubt exists in England concerning the merits of such devices. If there is too much lag in their response to rise in temperature, the danger point may have been passed before the motor is stopped.

In Germany one method of fire prevention employs two water-spray nozzles mounted above the driving pulley. The valves for them are electrically controlled by a small glass bulb filled with a liquid that expands and bursts the bulb when the surrounding temperature reaches 60° C. The glass bulb while intact keeps electric contacts separated in the valve-control circuit. It is understood that no special protective equipment is used in Belgium for belt installations.

In addition to protective devices at the drive end, a further precaution is to fireproof this area for 6 meters in each direction from the drive. Furthermore, a switch that can be operated from any point along the belt by a cord extending its full length is an important feature for stopping the drive motor in emergencies.

The importance of good housekeeping was stressed as a fire-prevention measure. It was considered essential not to allow coal to accumulate around rollers or along the belts. In Great Britain, belt roller supports are now required to be raised so that coal does not accumulate so readily around rollers.

Belts spliced with fasteners that leave a gap between the joined ends allow dust to fall through to the return side of the belts, contributing to spillage along the belts. It was found that this type of spillage could be reduced 95 percent by inserting neoprene strips in the gaps or by patching over the fasteners. In England a method of concentrating spillage at belt ends is under trial. This consists of reversing the belt at the drive end so that a clean belt travels back to the face. The disadvantage of this is that more space is required for the necessary equipment. Plastic belts have been found easier to keep clean than rubber belts.

Since authorities in Great Britain consider flame-resistant belts to be the best solution for the problem of fires, specifications and tests had to be drafted for determining flame-resistant properties and acceptability. To be approved for underground installation, belt samples must pass a friction as well as a flame test. In the friction test, a sample 5 feet long and 6 inches wide rests on a pulley or drum rotating at about 190 r.p.m., corresponding to an average belt speed of 330 f.p.m. One end of the sample is attached to a load-measuring device to check tension, and it is placed over the pulley so as to touch 180° of surface. The test is made both in still air and in an air current representing mine-ventilation current. The sample is regarded as having failed in either instance if flame or glow is detected or if the temperature of the drum exceeds 300° C.

For the flame test, 12 samples 12 inches long and 1 inch wide are used. These are held horizontally by 1 end, and a gas flame from a special burner is applied for 30 seconds at the other end; the top of the burner is 2 inches below the lower edge of the sample. Six samples are tested with outer covers intact; no flame or glow should be visible 3 seconds after the burner flame is withdrawn. The outer covers of the remaining 6 samples are stripped or buffed away, and the flame is applied as before for 30 seconds. Visible flame or glow must disappear in 5 seconds after withdrawal of the burner flame.

In constructing belts it was found essential to impregnate the individual cotton plies with PVC; otherwise, the belt would not pass the tests for flame resistance.

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Each belt approved for underground use must be branded with the date of manufacture, and each manufacturer is assigned a certain color to facilitate identification of his product. The date and color thus become useful in comparing the performance of one belt installation against another.

It was brought out during the conference that authorities in England were concerned over the possibility that static electricity generated by plastic belts in motion could ignite methane. Sparks 3 to 5 mm. long and quite bright had been observed underground at old belts along dry roads. To trained observers these sparks appeared to be capable of igniting methane, but tests were to be made to verify this opinion. It was learned later that laboratory tests had shown that as much as 40,000 volts of static electricity developed on dry days with plastic belts, as against only 1,000 volts with rubber belts. Sparks were noted where metal belt fasteners passed over rollers.

Apparently, the same concern over possible gas ignitions underground with belt installations in The Netherlands was not shared by a delegate from that country. He stated that laboratory experiments had shown it possible to ignite gas and that some static had been noted with new belts along dry roadways when the humidity was less than 60 percent but that with normal humid conditions underground there appeared to be little danger of gas ignitions by static sparks.

Several ways of reducing the development of static electricity were proposed in England. So-called static-free plastic belts already are being manufactured. One opinion is that metal clips at relatively close intervals along the belt edges would help to prevent building up of static charges by contact of the clips with the rollers. Another suggestion was that water sprayed on belts should help reduce static charges, although an excess would cause the coal dust to cake and adhere to the belts. In France it is thought advisable to mount belt rollers on insulators and to vulcanize over the metal fasteners.

## Flame Safety Lamps and Gas Detection

In spite of certain shortcomings, the flame safety lamp is still to be regarded as an important adjunct in insuring safety to underground workers at coal mines. This point was developed in Paper 23, Memorandum on the Detection of Fire-damp in Mines prepared by Dr. W. Maas of The Netherlands, and was also confirmed during the discussion. Although a considerable number of methane-detecting appliances have been devised, they do not indicate oxygen deficiency or concentrations of carbon dioxide. Accordingly, several countries are making efforts to improve safety lamps as to safety and reliability in gas detection.

The cerium-iron alloy pins used in relighting many safety lamps are regarded as dangerous. Dr. Maas' paper stated that abraded particles of the flint stone lodging in the heated gauze when the lamp was inverted caused ignition of gas surrounding the lamp. "Flint stone" is a term given to an alloy containing cerium, iron, and other ingredients. In discussing this problem with research specialists in England, it was learned that eight men in a mine-surveying group were burned in a gas ignition attributed to igniter particles in the gauze of a small lamp. The abraded particles when heated to 180° C., were found capable of igniting gas. In Paper 33, Dr. Karl Winter of Germany stated that, since a practical electrical igniter had been found, permits for use of lamps with cerium-iron igniters would be withdrawn after January 1, 1955, according to an order issued in December 1952 by the Mining Commission at Dortmund. Moreover, no new permits were to be issued after January 1, 1955, allowing the use of lamps with cerium-iron igniters.

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Among the lamps exhibited at the conference were some fitted with an electrical igniter. This igniter was operated by a rod through the bottom of the fuel vessel. When this rod is pulled down, 2 arms with a fine platinum wire or filament about 1/4 inch long between their ends are moved to bring the wire over the wick tube. The motion of the rod also closes a circuit from a dry cell through the filament, which causes it to glow and ignite the fuel vapor at the wick. Retracting the rod raises the filament to its original upright position and also disconnects it from the dry-cell circuit.

In a visit to the mining experiment station in Belgium, it was learned that lamps with cerium-iron igniters were not permitted in Belgian coal mines.

The most severe test for lamps suspected of being defective is to attempt to relight the lamp in motionless explosive atmospheres. Such a test is most likely to reveal defects of a nature that would produce external ignitions. This viewpoint was confirmed in a discussion with personnel at the Sheffield, England, experiment station. It agrees with the position of the Bureau of Mines, United States Department of the Interior.

The equipment for testing flame safety lamps in moving explosive methane-air mixtures at the Belgian experiment station is much the same as that used by the Bureau of Mines, United States Department of the Interior. Operation of the equipment was demonstrated by testing a lighted Davy safety lamp. This ignited the mixture passing the lamp, proving that it is unsafe in atmospheres moving at velocities of over 500 f.p.m. It was learned here, too, that in constructing double-gauze lamps, the space between the tops of the gauzes must be less than 15 mm.; otherwise the lamp may be unsafe.

Improvement in the reliability and accuracy of flame safety lamps in detecting methane is being carefully studied in England at the Isleworth Laboratory, Central Research Establishment II, National Coal Board. Efforts are being directed toward developing a detector in which the flame of burning butane offers better characteristics than the ordinary flame in safety lamps.

## Methane-Detecting Appliances

An entire conference period was devoted to discussing methane-detecting appliances. Two papers (10 and 33) had been prepared for the purpose. From the questions asked during the period it was apparent that the various countries are looking for portable methane-detecting instruments that are more suitable and accurate than flame safety lamps. Considerable interest was shown in the characteristics of American- and Japanese-made detectors, and it was learned that several types are being studied in several laboratories. In addition to the Riken interferometer type recently introduced into the United States, two others based on the same principle were found to be under study in Europe. One of these was made by the Seisakusho Co., Ltd., of Japan and the other by Carl Zeiss, Inc., in Germany. A "Mono" continuous methane recorder manufactured by H. Maihak A. G., Hamburg, Germany, was seen at the testing station in Belgium. This recorder employs an air turbine to drive a generator that supplies electric current for the combustion chamber. A clock movement drives the chart on which the record is made. The instrument can be set to give an alarm when the methan exceeds a predetermined value. A 0.25-percent error of indication is understood to be allowed in methane detectors in Belgium.

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## Methane Drainage

The large quantities of methane liberated in some Belgian mines have commercial value. Evidence of this fact was obtained in a visit to the office of the John Cockerill mine at Frameries, Belgium. Pipes cemented into holes drilled 60 to 100 meters deep into the coal seam and 25 meters apart are connected to a common main which hourly delivers on the average of 600 cubic meters of gas containing 75 percent of methane to a gas holder fed from several mines. From this point it is distributed to nearby factories. When the heating value of the gas from the mine drops below a prescribed value, an automatic device operates to stop flow of gas to the holder.

## Explosion-Proof Mine Equipment

One of the demonstrations witnessed by delegates at the Dortmund-Derne experiment station was that showing the conditions under which ignition of explosive atmospheres surrounding an electric enclosure would occur in one instance but not in another. A cast-aluminum-alloy enclosure or box was used for this demonstration. Instead of being bolted, the cover was of sliding type, designed so that one side of it engaged with a tight-fitting groove machined in the box and a similar groove at the opposite side engaged with a lip of the box when the cover was in place. This design left 2 matching plane surfaces at the 2 ends of the box serving as flame paths with no means of keeping the plane surfaces together except the overlap of the grooves in the cover and box at the sides. The gap between these surfaces was said to be 0.3 mm.

The box was mounted in an upright, cylindrical testing chamber or gallery so that it could be filled and surrounded with an explosive mixture of "coal gas" and air. The gallery was approximately 4 feet in diameter by 4 feet in height and was closed at the top with a waterproof paper diaphragm resting on a rubber ring gasket. The diaphragm was held in place merely by resting an angle iron ring on it without fastenings of any kind.

For the first test, the mixture within the box was ignited by a high-tension electric spark. No external ignition occurred under this condition. For the next test, the mixture within the box was ignited by vaporizing a copper wire with short-circuit current. The copper wire was 1.5 sq. mm. in sectional area (between No. 15 and 16 A.W.G.) and 100 mm. (4 inches) long. In this instance the mixture surrounding the box exploded. The ignition was explained as being caused by incendive particles of the aluminum alloy box projected through the 0.3-mm. (0.012-inch) cap in the joint at the end of the box. Because this condition produced external ignitions, certification of this type of construction was no longer permitted after January 1, 1954. Accordingly, in subsequent boxes, a tongue-and-groove design was used for the joints at the two ends instead of plane surfaces.

In Europe the criterion for failure of an enclosure to meet explosion-test requirements is commonly the fact that the surrounding atmosphere ignited. In conducting the tests, observations for discharge of flame, sparks, and smoke from joints or clearance openings in the enclosure are not always made. This practice differs from that followed in the United States by the Bureau of Mines, United States Department of the Interior, in that observations are always made to determine where flame, sparks, and smoke are discharged. Moreover, if flames are noted, the enclosure is recorded as having failed to meet test requirements, even though no external ignition occurred.

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The testing station at Dortmund-Derne is well equipped for explosion testing. The electrical testing laboratory was built within the last 2 years. Generating equipment capable of delivering high current at high voltage is available for making short-circuit and other electrical tests that may be desirable. This equipment includes a rotary converter with a maximum output of 400 kv.-a., which is designed for use within voltage limits of 0 to 800 volts, direct current, and 0 to 1,200 volts, alternating current. Also available is a turbogenerator capable of producing surge currents up to 20,000 a., effective. A transformer in the high-voltage test apparatus allows energy outputs up to 600 kw. in the range of 1.2 to 11 kv. In addition to the gallery previously mentioned, other cylindrical galleries are used in making explosion tests of electrical equipment. The vertical galleries are for testing smaller pieces of apparatus, while a horizontal gallery in sections is for testing the larger pieces. A 5-ton, hand-operated gantry crane is available for handling pieces for testing and for manipulating parts of the galleries. The testing facilities are described in Paper 42.

Four papers (11, 22, 42, and 45) bearing on the subject of explosion-proof enclosures had been prepared for discussion at the conference. Judging by the number of questions asked, there was considerable interest in the method followed in determining explosion-proof qualities of equipment in the United States, as described by Paper 11. Also, there was much interest in the type of construction followed in this country. The experience in the United States with distortion of enclosures under test was verified by that in The Netherlands, as expressed in Paper 22. This paper described an electrical method devised for measuring the amount of permanent, as well as temporary, distortion produced at the joint between an enclosure and its cover by an internal explosion.

The Belgian gallery for explosion testing of equipment is a horizontal structure; one end is closed with a door to permit entrance of equipment to be tested and personnel. A track is laid into the gallery so that a truck bearing the equipment for test may be taken in and out easily. Since ignition of the external mixture is the determining factor in recording failure under test, observers are not always stationed at the gallery windows. The source of ignition is usually at the center of the enclosure under test. This same gallery is used to test diesel locomotives.

Among the Belgian requirements for constructing explosion-proof electrical equipment is the limit of 0.1 mm. maximum separation of surfaces comprising flange joints 25 mm. wide and a 0.5 mm. maximum for joints 50 mm. wide. A minimum of 10 mm. is prescribed as the distance from the inside of an explosion-proof enclosure to the edge of a bolt hole through the flange joint. Flame arresters used for either electric or diesel equipment are required to have a path 50 mm. long between nonrusting plates. The plates must be 2 mm. thick, and the space between them must not exceed 0.5 mm.

In explosion-testing electrical equipment at the French experiment station, five tests usually are considered sufficient, and these are not always observed. Ignition of explosive mixtures surrounding an enclosure is the criterion for failure under test. The tests are made in cylindrical galleries having a vertical axis. Flame arresters used with explosion-proof electrical equipment must have plates giving a flame path at least 25 mm. long between them. The plate separation must not exceed 0.5 mm.

Various laboratories in England have studied problems associated with the design and construction of explosion-proof enclosures for electrically operated mining

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machinery. At Buxton, in the laboratory of the Safety in Mines Research Establishment, for example, much experimental work has been done toward establishing "safe-gap" values. A safe gap may be defined briefly as the maximum separation between surfaces comprising joints that will not permit propagation of explosions within an enclosure to the surrounding explosive atmosphere. In testing enclosures for explosion-proof qualities at Buxton, it is seldom considered necessary to observe the enclosure directly. Failure under test is recorded only when the explosive atmosphere surrounding the enclosure is ignited by flames issuing from it.

Considerable interest was manifested in Europe toward a proposed international standard for constructing explosion-proof (flameproof) equipment. This was particularly evident in England through discussions with individuals and groups. For example, in a meeting in London with the British delegation preparing to visit the United States to attend sessions of the International Electrotechnical Commission at Philadelphia, opportunity was afforded to explain the Bureau of Mines requirements and methods of testing equipment for official approval.

## Gas Ignitions by Frictional Sparks

Paper 5, Ignition of Explosive Gas Mixtures by Friction, brought out a very interesting discussion in one of the sessions of the Dortmund-Derne conference. It was learned that tools, such as hand-held drills, made of aluminum and magnesium alloys and props made of these metals were to be prohibited in safety-lamp mines of England after the close of 1954. One reason for this ruling was to prevent gas ignitions by sparks produced when such metals strike rusty steel.

In Germany, it was thought that ignitions from this source need not give grave concern as the magnesium content of light alloys usually was less than 1 percent. Opposed to this viewpoint however, was the opinion that until 2 years ago, ignitions attributed to unknown causes might actually have been caused when a light alloy struck an oxygen carrier (rust) and produced a thermit action.

It was stated that in Belgium sparks produced by light alloys have been suspected as a possible source of gas ignitions underground.

Gas ignition by sparks produced by cutting-machine bits has been the subject of special studies in England. This topic was discussed during the visit to the Buxton station. It was learned that some 10 ignitions a year occur when cutting machines are operated without water on the bits. On the other hand, there have been no reports of ignitions when cutting is done wet. When water was used on an experimental disk for producing sparks, it was found that the chance of ignition was reduced 50 percent. Air carried into the kerf by the water stream was said to help ventilate the undercut. But, if air is piped to the machine to ventilate the undercut, some arrangement such as an interlock between the air and electrical control would be necessary to insure that the air is turned on before the cutter bits are started. On the other hand, if methane is present in amounts above the upper explosive limit, air must be added with caution, as it might bring the mixture within the explosive range. Creating an inert atmosphere in the kerf with some gas such as nitrogen was thought to be a feasible way of reducing the ignition hazard. A search is being made for a special flowmeter type of valve to use on continuous mining machines so that the machines would be inoperative unless water is flowing to the cutting bits.

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## Multiple-Shot Blasting

Four papers (9, 21, 32, and 43) dealing with the subject of safety in blasting were discussed at the conference in Dortmund-Derne. Germany, it was stated, had no difficulties in multiple blasting when instantaneous electric detonators were mixed with short-delay detonators. One interesting comment was that adequate training of drillers and shot firers was important.

Small portable units are available in Germany for testing multiple-shot blasting machines. These are cylindrical, wax-filled boxes about 2 inches in diameter. The blasting machine to be tested is connected to two terminals in the top of the unit and when operated will light a small neon lamp under a glass-covered opening if the blasting machine is in satisfactory condition.

During the visit to the Belgian testing station it was learned that multiple blasting is permitted in mines of that country with up to 10 short-delay detonators in series. In discussing the advisability of mixing instantaneous with short-delay detonators in series for multiple shooting, the opinion was given that there should be no objection from the standpoint of possible misfires. However, in a demonstration arranged to substantiate this point, a zero-delay detonator was used as an instantaneous detonator in a series of 18 delay detonators having 25 to 30 milliseconds delay intervals. All 18 detonators fired when connected to the blasting unit. One type of blasting unit used in Belgium is spring operated. The key used to wind the spring also is used as the firing key, and the unit is designed so that the key cannot be removed for firing until the spring has been completely wound. Thus, variations in manual effort are eliminated as a factor in obtaining maximum output of blasting units. It is the opinion that blasting units (exploders) should be designed so that current will cease to flow in the blasting circuit at the end of 4 milliseconds.

A demonstration of the possibility of gas ignition by short-delay detonators was witnessed at the Belgian testing station. For this the detonator was suspended freely in a vessel containing an explosive gas-air mixture. Although the mixture was not ignited each time a detonator was fired, ignitions were frequent enough to prove that safeguards are necessary when these detonators are used in gassy mines. The opinion in Belgium is that there is a greater hazard of gas ignitions when multiple blasting is done in rock than in coal.

Tests to determine hazards associated with blasting in rock are made in a tunnel driven in hard rock. In a demonstration arranged for the benefit of the author, 2 holes were drilled about 2 feet apart in a hanging corner of rock at the right of the tunnel face. The upper hole was drilled to a depth of 1 meter 18 centimeters and the lower hole to a depth of 1 meter. Each hole was charged with 6 cartridges of explosives. In the upper hole the last cartridge inserted contained a zero delay detonator pointed away from the main body of the charge, and a No. 6 delay detonator was similarly placed in the last cartridge in the second hole. Stemming was tamped in each hole after the primer was in place. The selection of detonators provided for a delay of about 180 milliseconds between shots. A paper diaphragm was erected outby the face, and enough methane was admitted back of it to form an 8.75-percent mixture.

When the shots were fired the explosive mixture did not ignite. Examination later disclosed that 1 cartridge had not exploded in the upper hole and 2 or more had not exploded in the lower hole. It was explained that in this type of test, the gas has never ignited when the delay between shots was under 60 milliseconds but that ignitions were likely to occur when the delay was over 100 milliseconds between shots.

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For studying the uniformity of detonator-timing characteristics, the equipment at the Belgian station includes a drum rotating at a constant speed of 200 r.p.m. covered with a photographic film which records the light flashes of the exploding detonators. The latter was inserted horizontally in holes possibly 3 inches apart in an upright piece of steel shafting, which is approximately 3 inches in diameter. The ends of the detonators are set to protrude about one-half inch beyond their holes in the shafting. The axis of the holes are at right angles to a vertical plane, which is determined by the axis of the shafting and the center of the lens in front of the photographic film. The sensitiveness of detonators is determined by apparatus that permits a predetermined value of current to flow for a chosen period of time. This period is adjustable through variable separation of two switches that are tripped in succession by the swing of a pendulum, the first one closing the circuit through the detonator and the second one opening the circuit. The duration of current flow is measured in milliseconds by a chronograph. A 20-volt battery supplies the firing current that is first adjusted through a circuit having a resistance equal to that of the detonator to be tested. Then, using switches, the battery is connected to the detonator circuit.

In France it was learned that no limit is placed upon the number of shots that can be fired simultaneously when multiple blasting is done in gassy mines. However, a 4-millisecond time limit is set as the maximum duration of current flow to the blasting circuit from multiple-shot blasting units.

Blasting units are tested in the laboratory at the Sheffield station in England. Six shots is the maximum number permitted during multiple blasting in British coal mines. A unit having a 67-volt dry battery and a 150-microfarad condenser was seen, including an instrument for determining the condition of the detonator circuit before firing. It had a scale divided into areas of different colors for indicating at a glance whether the circuit was normal, short circuited, or open circuited. The design was such that the switch for closing the firing circuit had to pass through the circuit-testing position before it could be moved to the firing position.

## Diesel Mine Locomotives

One of the factories in Germany supplying diesel-driven mine locomotives is that of the Swarz & Dyckerhoff Co. at Mulheim. In a visit to this plant it was learned that among the types built is a diesel locomotive for operation in gassy coal mines. This type is fitted with flame arresters made of plates spaced 0.8 mm. apart. Formerly, a spacing of only 0.5 mm. was permitted. Locomotives are equipped with "inertia" starters. For fire fighting, nozzles connected by piping to a cylinder of carbon dioxide in the operator's cab can be used to fill the space under the housing, surrounding the engine quickly with an inert atmosphere.

In discussing safety problems with officials in England, it was learned that 7 fires have occurred on diesel locomotives in 5 years in that country. Fortunately, the fires so far have been confined to the locomotives. One cause of these fires was found to be slipping of the V-belts used to drive auxiliaries such as fans and pumps on the locomotives. The suggested remedy was to use a positive drive by chain or gears, or else use belts made of flame-resistant material. Another cause of fires has been high temperatures reached on surfaces of exhaust-gas conditioners. Oil and coal dust collecting between the locomotive frame and conditioner have caught fire. Tests were to be run to determine whether water jackets or water-spray injection into the exhaust would reduce the temperature of conditioners. It was stated that carbon dioxide fire extinguishers fixed in the locomotive are not

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mandatory in England. It was also stated that the British standard for diesel locomotives eventually would closely resemble the requirements of the Federal Bureau of Mines as set forth in Schedule 22.3/ Plans are being drawn for a new test rig with which a complete locomotive can be tested under load.

## Underground Photography

During the visit to the laboratories of the Ministry of Fuel and Power at Sheffield, England, it was learned that photographs of underground conditions are used to a considerable extent in reports on mine accidents and disasters as well as for educational purposes. Photographs of conditions found in a mine following an explosion or fire prove to be invaluable in efforts to determine causes as well as to devise measures to prevent similar accidents in the future. A copy of Research Report 534/ was obtained. This publication describes methods employed and equipment used in making photographs in gassy coal mines. Although the publication is based on photography with approved self-contained portable lamps for illumination, explosion-proof lighting fixtures have since been developed, together with arrangements for connection to power circuits in the mine. The author was given photographs of this equipment.

## CONCLUSION

In the conference and in the visits to the various mining experiment stations, the desire to exchange information of benefit toward improving health and safety conditions underground was plainly evident. Specialists in different types of research offered ideas and recommendations freely.

Although much progress has been made, research will continue at the different experiment stations, and there will be further need to report on progress made. Opportunity to do so will be afforded at the next international conference. The proposal already has been made that Belgium and The Netherlands serve as hosts, with sessions divided between the two countries, during the summer of 1956.

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